NEW OPPORTUNITIES FOR REPRODUCTIVE MANAGEMENT

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ABSTRACT

The majority of reproductive management strategies are directed at providing the best production environment for adult animals. Obviously, this is necessary and appropriate. However, there is an increasing amount of evidence that supports the concept that there are key developmental periods during the maturation of young animals that are critical to their reproductive success as adults. In swine, one of these critical periods is the first 3 weeks after /birth which coincides with lactation on most swine farms. Several studies were conducted to examine the impact of reducing the litter in which future replacement gilts and boars were raised on their reproductive function as adults. The rationale for this strategy was that gilts and boars raised in small litters would have less competition, improved access to nutrition, and, thus, enhanced development during this critical period compared with their counterpart raised in a large litter. This, in turn, should result in better reproductive function as an adult. The study with sows is still in progress. However, through 3 parities, sows raised in litters of 7 piglets or less were less likely to be culled and had higher farrowing rates and larger litters than sows raised in litters of 10 or more piglets. The cumulative effect of these advantages was estimated to be an additional 1.1 piglets weaned per gilt that entered production. A separate study with replacement A.I. boars has just been completed. Boars raised in litters of 6 piglets or less reached puberty sooner, produced more spermatozoa per ejaculate, and appeared to be more fertile compared with boars raised in litters of 9 piglets or more. Assuming that a boar remains in a boar stud for at least 73 weeks and insemination doses consist of 3 billion spermatozoa, boars raised in small litters produced in excess of 380 more doses than boars raised in large litters over their productive life. Thus, it appears that enhancing the neonatal environment of replacement gilts and boars is a new opportunity for enhancing reproductive management.

INTRODUCTION

In 2007, sow replacement rates varied from 30 to 89% with an average of 68% for herds using the PigChamp® recording system in the U.S. and Canada (PigChamp, Inc., 2007). Several large retrospective studies have reported that females are most likely to leave the herd during entry-to-first service and weaning-to-service after their first lactation. Thus, the decision to remove a sow from the herd is largely based upon her failure to reproduce in a timely fashion, which is often referred to as "involuntary culling". The situation with boars is somewhat different. Most boars in North America are replaced 12 to 18 months after they enter production (Knox et al., 2007). This relatively short usage period is related to the need to maximize genetic improvement and typically is independent of a boar's performance. In other words, even outstanding boars would be culled to make room for the next generation. This type of culling is referred to as "voluntary culling".

Both types of culling limit the reproductive efficiency of swine herds. For sows, involuntary culling creates a situation in which the majority of females are being replaced before they reach their peak biological period of productivity which typically occurs between parities 3 and 6. For boars, voluntary culling occurs during a period of time when their semen production and fertility is still increasing and also before it has reached optimum levels. From a management perspective, most producers are faced with two different situations – one in which the longevity or productive life of sows needs to be increased and another in which the output of boars needs to be increased during a relatively short period of time.

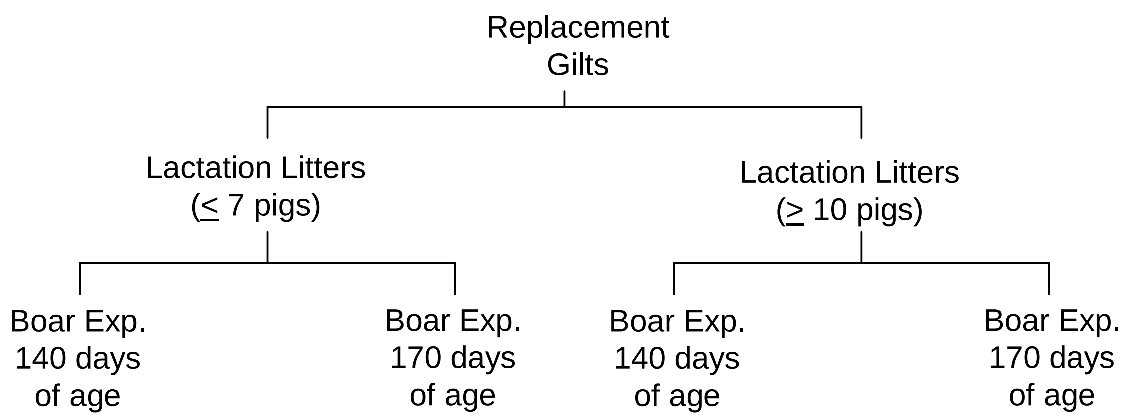
Most attempts to address these productivity issues have focused on the management of adult sows and boars and often produce equivocal results on commercial operations (Flowers, 1997; 1998). The observed variation in results with most of these intervention strategies suggests that they may be simply correcting problems inherent and unique to a given production environment. Obviously, this is very important, but typically does not elicit the same response on every operation.

From a physiological perspective, important developmental events occur in both gilts and boars shortly after birth. These events establish the reproductive tools that animal's have to work with as adults. In females, the number of egg nests and the formation of follicles in the ovary (Morbeck et al., 1993) and the size of the uterine endometrium (Bartol et al.,1993) increase during the first few weeks after birth. These are important observations because it means that there is a period of time shortly after birth during which management conditions have the potential to affect the number of eggs that sows can ovulate each time they are in estrus and the number of fetuses that their uteri can maintain each time they become pregnant as adults. Similarly, the cells in the testicles and secondary sex glands that are responsible for the production of sperm and seminal fluids undergo two periods of rapid development (McCoard et al., 2003) The first occurs during the first 3 weeks after birth and is thought to be the most critical for adult reproductive function. Consequently, the manner in which both potential replacement boars and gilts are managed early in life may present new opportunities for reproductive management. The primary objective of this paper is to present some relatively new information with regards to how management early in the lives of gilts and boars can influence their reproductive performance as adults.

MANIPULATION OF THE NEONATAL ENVIRONMENT AND SOW LONGEVITY

Currently, we are in the process of collecting data with regard to how manipulation of the neonatal environment of replacement gilts affects their lifetime productivity or longevity. In essence, we are attempting to determine if there are strategies that can be introduced early in the management of replacement gilts that will increase the proportion of sows that produce at least 3 parities. The study is being conducted within an 80,000-sow commercial production pyramid that uses "in-house" gilt multiplication. In this system, replacement gilts remained "on-site" until they were about 190 days of age; and then were sent to commercial farms. At birth, gilts were randomly allocated to a factorial arrangement of treatments involving neonatal litter size (≤7 litter mates or ≥10 litter mates); and puberty stimulation (boar exposure @ 140 days of age or boar exposure @ 170 days of age). The overall design of the experiment is shown in Figure 1. Between 190 and 210 days of age, gilts were sent to commercial farms. The commercial farms were P.R.R.S. positive, but considered to be P.R.R.S. stable. At the present time, all sows still in the herd have just weaned their third litter.

Figure 1. Outline of the experimental design for sow longevity study.



Results from the study are shown in Tables 1 through 4. The primary measure we used for sow longevity was the proportion of sows still in the herd after 3 parities (Table 1). Both being reared in a small litter and boar exposure at 140 days of age had a positive effect on sow longevity. The relative advantages were about 16% and 10% for being raised in a small litter and receiving boar exposure at 140 days of age, respectively. These effects were additive, so approximately 26% more sows raised in small litters and exposed to boars at 140 days of age were still in production after weaning three litters compared with their counterparts raised in large litters and exposed to boars at 170 days of age.

The primary measures used to evaluate reproductive performance in the study were farrowing rate (Table 2) and number of pigs born alive (Tables 3 and 4). Both being raised in a small litter and receiving boar exposure at 140 days of age had a tendency to increase farrowing rate over three parities. These effects were additive. Early puberty stimulation increased farrowing rate by 6.0%, whereas being raised in a small lactation litter resulted in a 4.0% improvement. As a result, sows that were raised in litters of less than 7 pigs and were given boar exposure at 140 days of age had a 10.0% higher farrowing rate compared with those that were not.

Table 1. Effect of neonatal litter size and puberty induction strategies on proportion of sows remaining in herd after three parities.

Puberty Stimulation	Neonatal Environment: Small Litters (≤ 7 pigs)	Neonatal Environment: Large Litters (≥ 10 pigs)	*Main Effect of Puberty Stimulation*
Boar Exposure @ 140 days	60.0% (180 / 300)	42.2% (133 / 315)	*50.9%[a] (313 / 615)*
Boar Exposure @ 170 days	46.0% (138 / 300)	32.6% (98 / 300)	*39.3%[b] (236 / 600)*
Main Effect of Neonatal Environment	*56.3%* (338 / 600)*	*37.6% (231 / 615)*	----------

*significantly different from Gilts raised in Large Litters ($p < 0.05$)
[a,b] means with different superscripts within the same column differ ($p < 0.05$)

Table 2. Effect of neonatal litter size and puberty induction strategies on farrowing rate over three parities.

Puberty Stimulation	Neonatal Environment: Small Litters (≤ 7 pigs)	Neonatal Environment: Large Litters (≥ 10 pigs)	*Main Effect of Puberty Stimulation*
Boar Exposure @ 140 days	88.7% (642 / 724)	83.9% (533 / 635)	*86.5%[a] (1175 / 1359)*
Boar Exposure @ 170 days	81.8% (539 / 659)	78.9% (446 / 565)	*80.5%[b] (985 / 1224)*
Main Effect of Neonatal Environment	*85.4%* (1181 / 1383)*	*81.5% (979 / 1200)*	----------

*significantly different from Gilts raised in Large Litters ($p < .10$)
[a,b] means with different superscripts within the same column differ ($p < 0.10$)

Table 3. **Effect of neonatal litter size and puberty induction strategies on average number of pigs born alive through three parities (numbers in parenthesis are number of observations).**

Puberty Stimulation	Neonatal Environment[1] Small Litters (≤ 7 pigs)	Large Litters (≥ 10 pigs)	*Main Effect of Puberty Stimulation*
Boar Exposure @ 140 days	10.8 ± 0.2* (642)	10.2 ± 0.2 (533)	*10.5 ± 0.2 (1175)*
Boar Exposure @ 170 days	10.4 ± 0.2 (539)	10.0 ± 0.1 (446)	*10.2 + 0.2 (985)*
Main Effect of Neonatal Environment	*10.6 ± 0.2* (1181)*	*10.1 ± 0.1 (979)*	----------

[1]Neonatal Environment x Puberty Stimulation interaction ($p < 0.05$)
*significantly different from Gilts raised in Large Litters ($p < 0.05$)

Table 4. **Effect of neonatal environment and puberty induction strategies on numbers of pigs born alive in parities 1, 2 and 3 (numbers in parentheses are numbers of observations).**

	Boar Exposure @ 140 days of age		Boar Exposure @ 170 days of age	
Production Status	Small Litter	Large Litter	Small Litter	Large Litter
Parity 1	10.2 ± 0.2 (249)	9.8 ± 0.2 (233)	10.0 ± 0.2 (235)	9.6 ± 0.2 (209)
Parity 2	10.8 ± 0.2 (213)	10.4 ± 0.2 (167)	10.4 ± 0.2 (166)	10.1 ± 0.2 (139)
Parity 3	11.5 ± 0.2 (180)	11.0 ± 0.2 (133)	11.0 ± 0.3 (138)	10.6 ± 0.2 (98)

There was an interaction between neonatal environment and puberty stimulation for numbers of pigs born alive. When puberty stimulation occurred at 140 days of age, sows raised in small litters had increased numbers of pigs born alive compared with sows raised in large litters. In contrast, when puberty stimulation occurred at 170 days of age, there was only a tendency for sows raised in small litters to have increased numbers of piglets. Because the interaction was one of magnitude, the overall main effect of neonatal environment was significant with sows being raised in small litters having about 0.5 pigs more per litter than those raised in large litters. There was no effect on puberty stimulation on numbers of pigs born alive.

Changes in numbers of pigs born alive for parities 1 through 3 are shown in Table 4. What is interesting to note from these data is that even though sows raised in small litters had an additional 0.5 pigs per litter over 3 parities, differences among various treatment combinations by the end of the third parity were quite large. For example, there was almost a pig per litter difference (0.9) for sows raised in small litters and given boar exposure at 140 days (11.5) compared with sows raised in large litters and given boar exposure at 170 days (10.6).

The results from this study illustrate clearly that the neonatal environment and the age at which puberty stimulation occurs has a significant influence on adult reproductive performance. Based on the differences observed in longevity, farrowing rates, and numbers of pigs born alive, estimates as to what production systems might expect to achieve with different management strategies was estimated. This was done by determining the number of litters each female farrowed and multiplying it by the average number of pigs born alive over three parities (Table 3) within each treatment. These estimates are shown in Table 5. Boar exposure at 170 days of age for gilts raised in a neonatal litter probably represents the most common gilt development strategies currently in the U.S. swine industry. Consequently, it seems logical to consider this as the treatment that best reflects what most production systems are currently doing. Based on the estimations presented in Table 5, simply limiting the lactational litter size of future replacement gilts to 7 piglets or less would increase the lifetime productivity of each sow that enters production by 3.3 pigs through 3 parities, or roughly by 1.1 pigs per litter. A similar improvement of 3 pigs would be expected by providing boar exposure at 140 days of age. If both were employed effectively, then one would expect an improvement of 6 pigs per female over 3 parities, or about 2 pigs per litter.

Table 5. Estimated effects of different gilt development strategies on total number of pigs produced per bred gilt over three parities.

Strategy	Number of Litters Farrowed / Gilt	Average Number Born Alive / Litter	Total Pigs / Bred Gilt
Boar exposure @ 170 days of age + Large neonatal litter size	1.60	10.0	16.0
Boar exposure at 140 days of age + Large neonatal litter size	1.86	10.2	19.0
Boar exposure @ 170 days of age + Small neonatal litter size	1.86	10.4	19.3
Boar exposure at 140 days of age + Small neonatal litter size	2.23	10.8	24.1

An important point to consider is whether these experimental treatments could be easily adapted into current commercial production systems. Given the management structure of many operations in the swine industry, providing good, consistent boar exposure to gilts at 140 days of age probably would be technically very challenging and present problems with maintaining strict biosecurity. Thus, it may not be practical for many operations. In contrast, because males born as litter mates to replacement gilts have limited economic value as market animals, strategic cross-fostering programs for sows nursing potential replacement gilts is a technique that should be easy to implement and improve sow longevity and productivity.

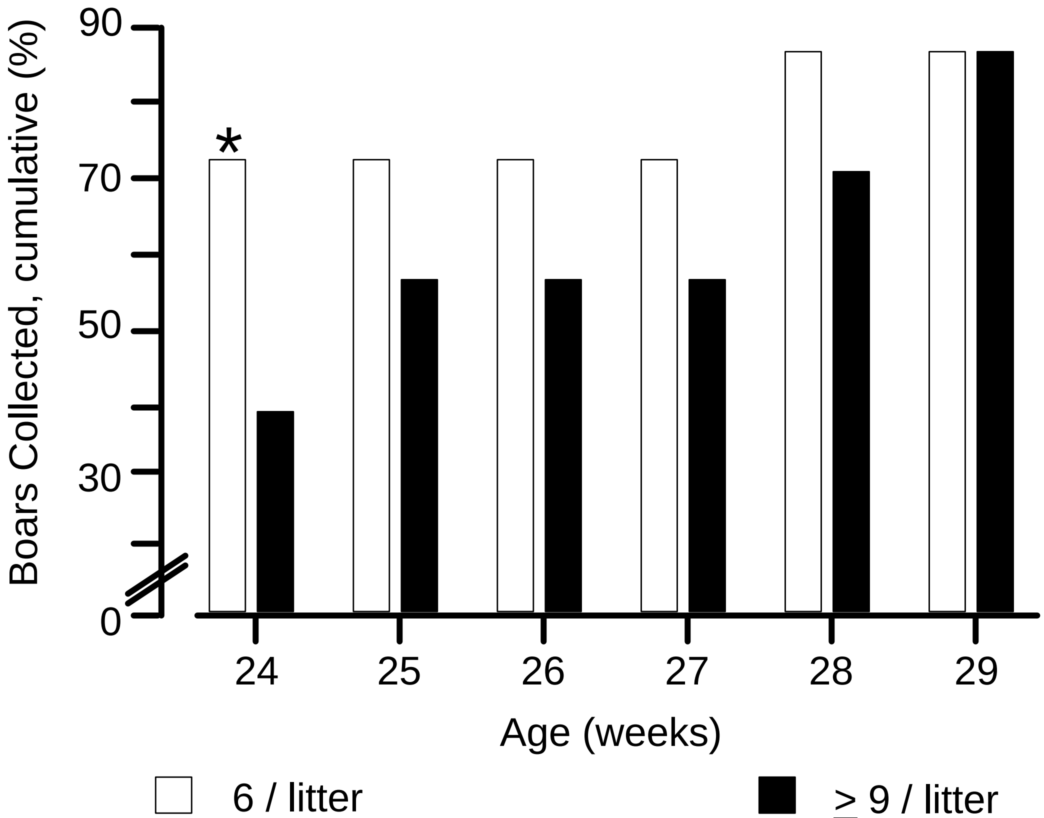
MANIPULATION OF THE NEONATAL ENVIRONMENT FOR A.I. BOARS

In order to examine the influence of the neonatal environment on adult reproductive performance, 40 terminal-line, crossbred boars were crossfostered at one day of age in such a way that littermates were raised in litters of 6 (n=20) or in litters of 9 or more pigs (n = 20). Boars were selected from birth litters that had equal numbers of gilts and boars and crossfostering was done in such as way that potential milk production difference among sows were minimized. For example, if sow A gave birth to 5 boars and 5 gilts and she was randomly selected to nurse a litter of 9 or more piglets, then 4 of her sons were fostered off to four different sows and she received 4 new boars from other sows, thus, creating a situation in which she nursed 5 different genotypes of boars. The study was conducted with a group of boars born in October and another group born in April creating a Fall and Spring replicate (n = 10 boars / treatment / season). The same sires were used to produce the experimental animals in each replicate.

Litters were weaned at 18 days of age and boars were managed according to normal industry practices through the nursery and finishing phases of production. The only exception was that boars were given 4 and 10 square feet of floor space per pig during the nursery and finishing phases, respectively. An important component of the experimental design was that boars from the small (6 pigs) and large litters ($\geq$ 9 pigs) were co-mingled at weaning. This created a situation in which animals from both treatments were in same pens from weaning through finishing. At 5 months of age, boars were moved from pens and housed in individual crates. At 5.5 months of age boars were trained for collection with a dummy sow and collected once per week until they were at least two years of age.

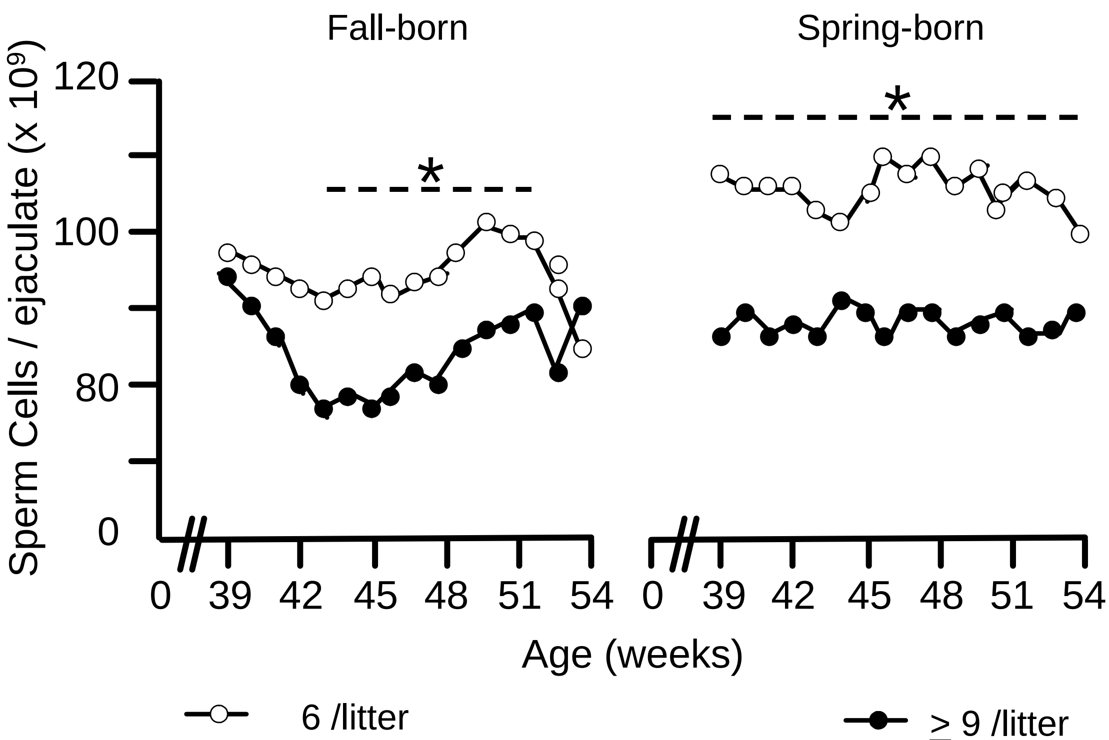
Training for semen collection began when boars were 24 weeks of age (~ 155 days of age). There were no differences in the number of boars successfully being collected by the end of the training period (Figure 2). However, the overall training period was significantly reduced for boars from small (10 days) than large litters (30 days). These data indicate that boars allowed to nurse in litters of 6 pigs or less had greater libido than boars nursing in litters of 9 or more pigs. Boars raised in small litters also had increased testicular size at relatively young ages compared with boars raised in large litters (data not shown). One interpretation of these data is that testicular maturation and thus testosterone production began earlier. This, in turn, should result in attainment of puberty at a younger age as measured by their desire to mount a dummy sow and be collected. It is particularly impressive that all 20 boars that nursed in small litters mounted and were collected during the first 5 days of the training period. In contrast, only 5 of the 20 boars that nursed in large litters were trained for semen collection during the first 5 days of the training period.

Figure 2. Effect of neonatal litter size on boars trained for semen collection on a dummy sow. *More boars raised in litters of 6 were trained to collect from a dummy sow compared with boars raised in litters of ≥ 9 (P < 0.05).



Numbers of spermatozoa per ejaculate are also greater in boars raised in small versus large litters. It is important to remember that there is a 6 month difference in age between the fall-born and spring-born replicates, so these data have been analyzed and presented separately (Figure 3). In the spring-born replicate, boars raised in small litters produced about 10 billion more spermatozoa per ejaculate about 75% of the time (61 weeks) between 42 and 112 weeks of age. In contrast, for those born in the fall, boars raised in small litters consistently had 20 billion more spermatozoa per ejaculate than their counterpart raised in large litters beginning at 39 weeks of age until the end of the study ended when they were 2 years of age. From a practical perspective, the collective advantage of being raised in a small litter was an additional 200 insemination doses (600 billion spermatozoa) for boars born in the Spring and an extra 567 insemination doses (1700 billion spermatozoa) for boars born in the Fall. No significant differences among treatments in motility, morphology, acrosome morphology, acrosin activity, or capacitation status were observed (Table 6).

Figure 3. **Effect of neonatal litter size on number of spermatozoa per ejaculate between 39 and 54 weeks of age. * Boars raised in litters of 6 produced ejaculates with more spermatozoa compared with boars raised in litters of ≥ 9 (P < 0.05).**



Finally, boars raised in small litters sired, on average, around 65% of the piglets resulting from heterospermic inseminations. Consequently, they appear to be more fertile than boars raised in large litters (Table 6). It is difficult to translate this relative advantage into differences in farrowing rate and numbers of pigs born alive at the present time. This is due to the fact that use of heterospermic inseminations and paternity testing of the resulting offspring is a relative assessment of fertility. In other words, it can be used to rank boars from most to least fertile. However, this technique cannot really establish whether the most fertile boar produces farrowing rates of 95% or 85%. Nevertheless, these data do indicate that regardless of what the actual fertility level, boars raised in small litters would be higher than those reared in large litters.

The same question that was posed for the study currently underway involving manipulation of the neonatal environment for gilts is equally valid for boars – is it practical under industry conditions? Given the fact that the productive life of an A.I. boar is so short and this is basically a voluntary decision based on enhancing the rate of genetic improvement, the answer is “yes”. Gilts from litters bred specifically for the production of A.I. boars also have limited usefulness sows and are most likely destined for market. In addition, most terminal line sows tend to have smaller litters compared with most maternal line sows. Thus, producers probably have more flexibility and a greater opportunity for strategic crossfostering in litters of replacement boars compared with those with replacement gilts.

Table 6. Semen quality and fertility estimates from boars raised in small or large litters during lactation (mean ± s.e.).

	Winter		Summer	
Variable	6 / litter	≥ 9 / litter	6 / litter	≥ 9 / litter
Motile spermatozoa (%)	85.3 ± 5.7	86.8 ± 6.5	88.4 ± 4.3	80.8 ± 5.7
Normal morphology (%)	91.3 ± 3.4	84.6 ± 4.5	88. 3 ± 5.1	82.1 ± 6.1
Normal acrosome morphology (%)	90.4 ± 4.7	83.2 ± 3.6	90.6 ± 6.1	80.3 ± 4.2
Acrosin activity (%)	95.3 ± 4.5	90.3 ± 3.2	92.8 ± 4.1	93.4 ± 4.6
Normal capacitation (%)	80.2 ± 7.8	70.3 ± 6.3	85.3 ± 6.9	79.7 ± 4.2
Seminal plasma proteins (relative units per ejaculate)	12.2 ± 2.4	10.1 ± 2.0	12.9 ± 2.1	10.7 ± 1.4
Proportion of piglets sired in heterospermic matings (%)*	67.3 ± 5.7	32.7 ± 5.4	63.5 ± 4.8	36.5 ± 4.3

* Boars raised in litters of 6 sired more pigs than boars raised in litters of ≥ 9 (P = 0.02)

CONCLUSIONS

Management of future replacement gilts and boars has a significant impact on their reproductive capabilities as adults. Strategies that reduce competition and enhance growth during the first 3 weeks of life positively affect the longevity and prolificacy of sows and the numbers and fertility of spermatozoa produced by boars. Reduction of the number of piglets in which replacement gilts and boars are raised is one such strategy that appears to be effective from both a practical and biological perspective.

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